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THE INFLUENCE OF RELATIVE AREA IN INTERTILLED AND OTHER CLASSES OF CROPS ON CROP YIELD.

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Experience has taught that there is a limit to the extent to which land may be occupied by the same class of crops without detriment to crop yield. This experience led gradually to the adoption of some form of crop rotation which would tend to prevent any given crop from occupying the same land often enough to be injurious. However, just what proportion of the crop area should be planted to intertilled crops, what to grain crops, and what to perennial grass, to prevent serious injury to the soil, are questions that the farmer has always had to answer for himself, largely from his own experience or from the established custom of his locality.

The fact that there are a number of requirements that crops must satisfy other than that of maintaining soil fertility frequently causes the requirements of the soil to be disregarded temporarily in the face of some greater need. This may explain in part why so little definite information is available which would enable the farmer to distribute his crops so as to favor high production.

That there is an optimum percentage area of the farm which may be devoted to a single class of crops for maximum yields per acre is indicated by the results of the investigations outlined in this paper. This area may be expected to vary somewhat on different types of soil, under different systems of farming, as well as with many other conditions. It is believed that the data here presented throw some light on this important subject, and it is hoped that their publication may lead to further investigation along this line.

During the past two years studies as to the relation of the type of farming to the maintenance of crop yield have been made on 240 farms in Chester County, Pa., and on 303 farms in central Illinois. These studies were made in the form of surveys similar in character to the regular farm management survey, except that instead of having for its object the financial status of the farm, the purpose was to find the influence of various systems of farming on the crop-producing capacity of the farm. Labor income is used as the measure

of efficiency in producing profits; the crop index¹ has been similarly used here as the measure of efficiency in maintaining crop yield.

In making these surveys an attempt was made to secure data on everything that might in any way affect the crop yield. The present paper, however, is limited to a study of cropping systems in their relation to crop yields in the localities mentioned, with only such incidental reference to the manure supply as is made necessary by the interrelation of cropping systems and practice in the use of manure. The soil covered by each of these surveys was some form of silt loam. Use has also been made of two other surveys which contained data bearing on this subject, one covering 377 Chester County, Pa., farms, and another 300 farms in Lenawee County, Mich.

RESULTS OF STUDY.

In making this study the farm crops were divided into three classes, viz., intertilled, annuals not intertilled, and perennials. The results of the investigations as to the influence of each of these classes of crops on crop yield indicate:

1. That there seems to be in all districts so far studied an optimum percentage of the crop area of the farm which can be devoted to a single class of crops and maintain maximum yields. Even under the rather intensive types of farming prevailing in Chester County, Pa., and in Lenawee County, Mich., and under the more extensive type of farming in Central Illinois the optimum area of intertilled crops in each case falls within 5 per cent of each other, the range being about from 32 to 36.
2. That when more than this percentage of area is devoted to a single class of crops, yields decrease even where there is an increase in the number of live stock per acre.
3. That the area devoted to small grain in Chester County, Pa., is so small that either it does not directly affect crop yield or its influence is completely masked by the effect of the amount of manure available.

¹ The crop index may be defined as the crop yields of a particular farm expressed in percentage of the average crop yields of all the farms in the community. It is found as in the following example:

A particular farm produces—

2,000 bushels of corn on	40 acres,
1,200 bushels of wheat on	40 acres,
900 bushels of oats on	30 acres, and
120 tons of hay on	80 acres.

Total..... 190

The average yields of the above crops in the community are: Corn, 60 bushels; wheat, 32 bushels; oats, 40 bushels; and hay, 1½ tons per acre. Hence, on the average, the areas required to produce the above quantities of the products mentioned are—

$$\begin{aligned}
 2,000 \div 60 &= 33.3 \text{ acres of corn,} \\
 1,200 \div 32 &= 37.5 \text{ acres of wheat,} \\
 900 \div 40 &= 22.5 \text{ acres of oats, and} \\
 120 \div 1\frac{1}{2} &= 68.6 \text{ acres of hay.}
 \end{aligned}$$

Total=161.9

Thus, it requires 190 acres on the farm in question to produce what 161.9 acres produces on the average. Hence, 1 acre produces on this farm $161.9 \div 190$, or 85.3 per cent as much as the average acre of the community.

4. That in Chester County, Pa., the optimum percentage area for perennial grass (in this case timothy and clover) is about 36 per cent of the crop area of the farm.

5. That data of this character make it possible to construct a cropping system which should, under average conditions, produce maximum yields with a given quantity of manure. In the case of Chester County such a system constructed from the data brought out in the 1912 survey corresponds very closely to the practice of those farmers on the one hand who maintain high yields, and with those on the other who have made highest profits. It thus becomes possible to detect a faulty cropping system and show how it may be improved.

CLASSIFICATION OF CROPS AND THEIR RELATION TO CROP YIELD.

Farm crops may be divided into three classes, viz, (1) Intertilled crops, such as corn, potatoes, and tobacco, which are usually planted in rows and cultivated between the rows; (2) annual crops not intertilled, consisting of grain and annual grasses which are usually sown broadcast and cut either for grain or for hay; and (3) perennial grasses, of which timothy and clover are the most common types in the regions studied and which are usually cut for hay or used as pasture.

RELATION OF INTERTILLED CROPS TO CROP YIELD.

To ascertain the effect, if any, of this class of crops on crop yield the 240 farm records from Chester County, Pa., were divided into four groups, based on the percentage of the crop area of the farm in intertilled crops.

TABLE I.—*Relation of per cent of crop area in intertilled crops to crop index in Chester County, Pa. (1914 survey).*

Number of farms.	Per cent of crop area in intertilled crops.		Average number animal units ¹ per 100 acres in crops.	Average crop index.
	Range.	Average.		
72	Less than 25.....	20.8	37.6	96
58	25-30.....	27.4	41.2	100
53	30-35.....	32.7	48.4	105.2
57	35 or more.....	41.4	53.4	104.7

¹ An animal unit is a mature horse or cow or as many smaller animals as require the feed of a horse or cow, namely, 2 head of young cattle, 5 hogs, 7 sheep, or 100 heus.

It will be observed that in Table I the crop index increased as the percentage of crop area in intertilled crops increases until the third group (30 to 35 per cent) is reached, after which it tends downward.

A similar tabulation of data from 303 farms in central Illinois is shown in Table II.

TABLE II.—*Relation of per cent of crop area in intertilled crops to crop index in Central Illinois (1913 survey).*

Num- ber of farms.	Percent of crop area in intertilled crops.		Average number animal units per 100 acres in crops.	Average crop index.
	Range.	Average.		
75	Less than 37.5.....	28.4	19.3	102
72	37.6-48.9.....	43.3	18.1	103
82	49-59.9.....	53.9	17.7	100
74	60 and over.....	73.6	15.8	93

A comparison of the two tables shows, first, that the percentage area of intertilled crops in Illinois is much larger than it is in Pennsylvania; second, that the crop index increases with the increase in the percentage of intertilled crops from the first group (less than 37.5 per cent) to the second (37.6 to 48.9 per cent), after which it declines.

Table III shows similar data for 300 Michigan farms.

TABLE III.—*Relation of per cent of area in intertilled crops to crop index, Lenawee County, Mich. (1912 survey).*

Num- ber of farms.	Per cent of crop area in intertilled crops.		Average number animal units per 100 acres in crops.	Average crop index.
	Range.	Average.		
59	Less than 21.2.....	16.9	22.7	97
60	21.2-26.....	23.8	30.2	100
60	26.1-30.9.....	29.2	31.0	103
62	31-37.....	34.6	31.9	103
59	37 and over.....	44.9	31.2	100

Here the crop index increases slightly from the first group to the third, remains constant through the fourth, and drops in the fifth. An average of the farms comprised in the third and fourth groups indicates that the high point of the crop index falls at about 32 per cent for intertilled crop.

In Table IV the crop index begins at 100.3 and drops in the next group to 98.9 in spite of the increase in percentage of area of intertilled crops and in animal units. This may be due to the fact that the small percentage of crops of the character in question prevents their becoming a determining factor. From this point the crop index rises to 106 in the fourth group and drops to 104.6 in the fifth, the optimum percentage area being about 36 or 37 per cent.

TABLE IV.—*Relation of per cent of area in intertilled crops to crop index in Chester County, Pa. (1912 survey).*

Num- ber of farms.	Per cent of crop area in intertilled crops.		Average number animal units per 100 acres in crops.	Average crop index.
	Range.	Average.		
75	Less than 33.....	18.7	22.5	100.3
76	23.1-26.1.....	24.7	23.3	98.9
78	26.5-30.5.....	28.5	30.6	102.5
73	30.6-35.5.....	33.0	33.3	106.0
75	35.6 and over.....	42.4	37.7	104.6

The results are shown graphically in figure 1, where smooth curves are drawn in such manner as best to fit the data.

These tables refer to farms in regions where the climatic conditions, soil, and types of farming are in some respects quite different. The soils of Pennsylvania are granitic, comparatively low in humus and lime, and the type of farming more or less intensive. The soils of

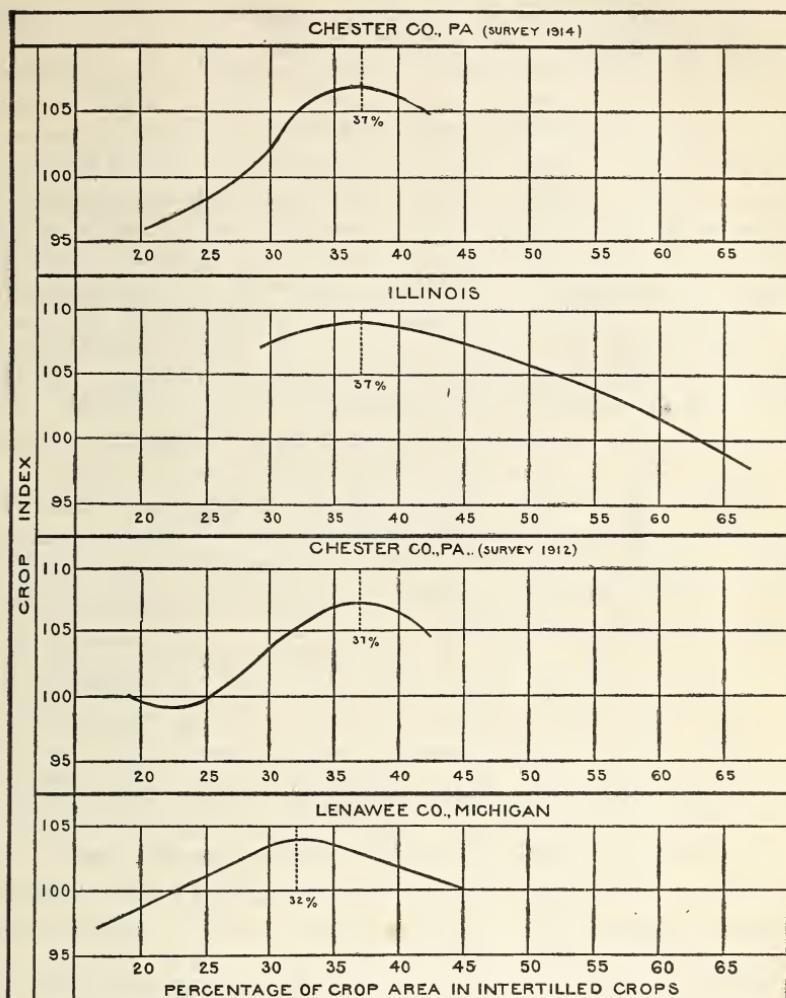


FIG. 1.—Relation of crop index to percentage of crop area in intertilled crops.

Illinois, on the other hand, are of glacial origin, relatively rich in humus and lime, and the type of farming distinctly extensive. In Michigan the soils are silt loam of glacial origin, and the type of farming more or less intensive, although not so much so as that in Chester County, Pa.; the principal enterprise is dairying. In spite of these differences in the three regions, however, the extent to which intertilled crops can be grown for best results appears approximately

the same, the total range of variation being about 5 per cent. This variation is no doubt due to differences in the conditions existing in the regions studied, chief of which may be the differences in soil and type of farming. It is to be noted that in all these localities the soils are silt loams. Whether studies on soils of different physical composition would give different results has not yet been determined.

In pursuing this study the question naturally rises, Is the manure returned to the land a disturbing factor in the tables just presented? To determine this the number of animal units for each 100 acres in crops in each group are inserted in the tables. It will be noted that in Tables I and IV the number of animal units per 100 acres of crops increases at almost the same rate as the area in intertilled crops. In fact, had the classification been made on the basis of animal units the distribution of farms would have been about the same. It is known that where manure is a dominant factor in maintaining crop yield the crop index rises with the increase of stock on the farm. In these cases, however, the increase in the crop index stops with the third group in Table I and in the fourth group in Table IV, indicating that the increased area in intertilled crops has become the dominant factor, and also indicating that the destruction of humus in the soil by the increased surface tillage is not fully counterbalanced by the increased quantity of manure supplied.

In Table I it also appears that the percentage area in intertilled crops is the dominant factor because the number of animal units per 100 acres in crops decreases as the area of intertilled crops increases. The crop index rises slightly at first, although there is a slight decrease in the number of animal units.

In Table III the number of animal units per 100 acres in crops rises in about the same proportion as the area in intertilled crops until the third group is reached, where it remains practically constant through the remaining groups without having any apparent effect on the crop index, which reaches its climax in the third and fourth groups and goes down in the fifth.

RELATION OF ANNUAL CROPS NOT INTERTILLED TO CROP YIELD.

Attention is now called to the position occupied by the other two classes of crops and their relative influence in the cropping system in Chester County, Pa. (1914 survey).

Table V is based on the per cent of the crop area in grain and other annual crops not intertilled.

TABLE V.—*Relation between the per cent of the crop area in annual crops not intertilled and crop index in Chester County, Pa. (1914 survey).*

Number of farms.	Percentage of the crop area in annual crops not intertilled.		Number of animal units per 100 acres in crops.	Average crop index.
	Range.	Average.		
64	Less than 18.....	14.2	51.9	105
73	18-24.....	20.6	44.5	102
48	24-30.....	26.9	39.8	99
53	30 and over.....	34.9	36.8	97

In this table the crop index decreases quite regularly as the per cent of annual crops not tilled increases, but at the same time the number of animal units decreases in just about the same proportion as does the crop index. In this case the decrease in crop index may be due to the decrease in the amount of manure available. Within the limits of this table there is no certain indication that the crop index is materially influenced by the proportion of crops of this class. If there is any such influence, it is completely masked by that of the manure applied.

RELATION OF PERENNIAL GRASS TO CROP YIELD.

In the third class of crops, shown in Table VI, there is a distinct rise in the crop index from the first to the second group. Here, too, the rise is made in spite of a falling off of the number of animal units, indicating that the percentage of perennial grass is the dominant factor, and that the optimum area is somewhere between 32 and 39 per cent of the crop area. Beyond this point there is a gradual decrease in the crop yield, due most likely to a greater amount of hay being sold, as indicated by the smaller number of animals kept.

TABLE VI.—*Relation of per cent of crop area in perennial grass to crop index Chester County, Pa. (1914 survey).*

Number of farms.	Per cent of crop area in perennial grass.		Number of animal units per 100 acres in crops.	Average crop index.
	Range.	Average.		
64	Less than 32.....	22.9	46.7	102
48	32-39.....	34.7	44.8	105
57	40-45.....	41.7	44.2	102
69	45 and over.....	51.7	40.8	98

CONCLUSION.

This analysis seems to point pretty definitely to percentage areas that may be devoted to two of these classes of crops, and, by exclusion, the third as well, for best results in the maintenance of crop yield in Chester County, and affords a foundation for the construction of a practical cropping system for that section. Thus, allowing about 10 per cent of the crop area for various crops not in the rotation, such as garden, orchard, soiling crops, etc., there should be in the cropping system about 36 per cent of the crop area in intertilled crops, about 36 per cent in perennial grass, and the remaining 18 per cent in annual crops not intertilled. To illustrate how nearly this corresponds to the actual practice of the most successful farmers, Table VII shows the crop area percentages of the 27 Chester County farms having the highest yield, and of the 27 having the lowest yield, in comparison with the percentages which the foregoing tables indicate as representing the optimum.

TABLE VII.—*Average percentage of area of intertilled crops, annual crops not intertilled, and perennial grass, Chester County, Pa. (1914 survey).*

Class of crops.	Average percentage.				
	1 On 240 farms.	2 On 27 farms showing highest yields.	3 On 27 farms showing lowest yields.	4 Modified for—	
	Highest yields.	Highest profits. ¹			
Intertilled.....	28.4	34.0	27.4	36	34-43
Annuals not intertilled.....	22.3	18.8	23.4	18	10-19
Perennial grass.....	38.0	38.2	39.4	36	2 40-50
Garden, orchard, etc.....	11.3	9.0	9.8	10

¹ The figures in the last column of Table VII are derived from data obtained in a farm management survey in Chester County, 1912.

² All hay crops, including annuals.

A comparison of columns 2, 4, and 5 shows that in actual practice the 27 farms showing the highest yields more nearly approach the figures obtained from Tables I, V, and VI than the others do.

Table VIII is a detailed version of Table VII, showing the distribution of area percentages among the several crops.

TABLE VIII.—*Showing the grouping and per cent of area of the individual crops which make up the classes and figures in Table V (1914 survey).*

Fields.	Crop.	Per cent of crop area.				
		241 farms.	27 farms having highest yields.	27 farms having lowest yields.	Modified for—	
			Highest yields.	Highest profits. ¹		
1	Corn.....	18.7	18.2	19.0	18.0	15.0 corn.
	Corn (ensilage).....	5.2	11.2	4.4	12.0	15.0 ensilage.
2	Potatoes.....	4.5	4.6	4.0	4.0
	Soy beans.....	2.0
3	Oats ²	5.1	3.6	5.8
	Wheat.....	17.2	15.2	17.6	18.0	4.0 potatoes, 11.0 soy beans.
4	Grass.....	19.0	19.1	19.7	18.0	15.0 wheat.
5	Do.....	19.0	19.1	19.7	18.0	15.0 hay.
6	Garden, orchard, etc.....	11.3	9.0	9.8	10.0	15.0 hay. 10.0.

¹ 1912 survey. The nearest practicable approach to percentage area producing highest profits.

² Farm management studies in Chester County, Pa., show that oats occupy a very small place on the average farm. The State experiment station and many progressive farmers have found that soy beans are better adapted to a place in the cropping system of these farms than oats are, and that they are growing in favor. In the construction of Table VIII soy beans have been substituted for oats in the last two columns.

The nearness with which the cropping system for high crop yield comes to coinciding with the one made out on the basis of high profits indicates that a well-balanced type of agriculture prevails in Chester County, Pa., a most satisfactory condition for any section. Where this condition does not prevail high yields are obtained at the sacrifice of profit or high profits are made at the sacrifice of soil fertility.



